The complex inner disk of the Herbig Ae star HD 100453 with VLTI/MATISSE

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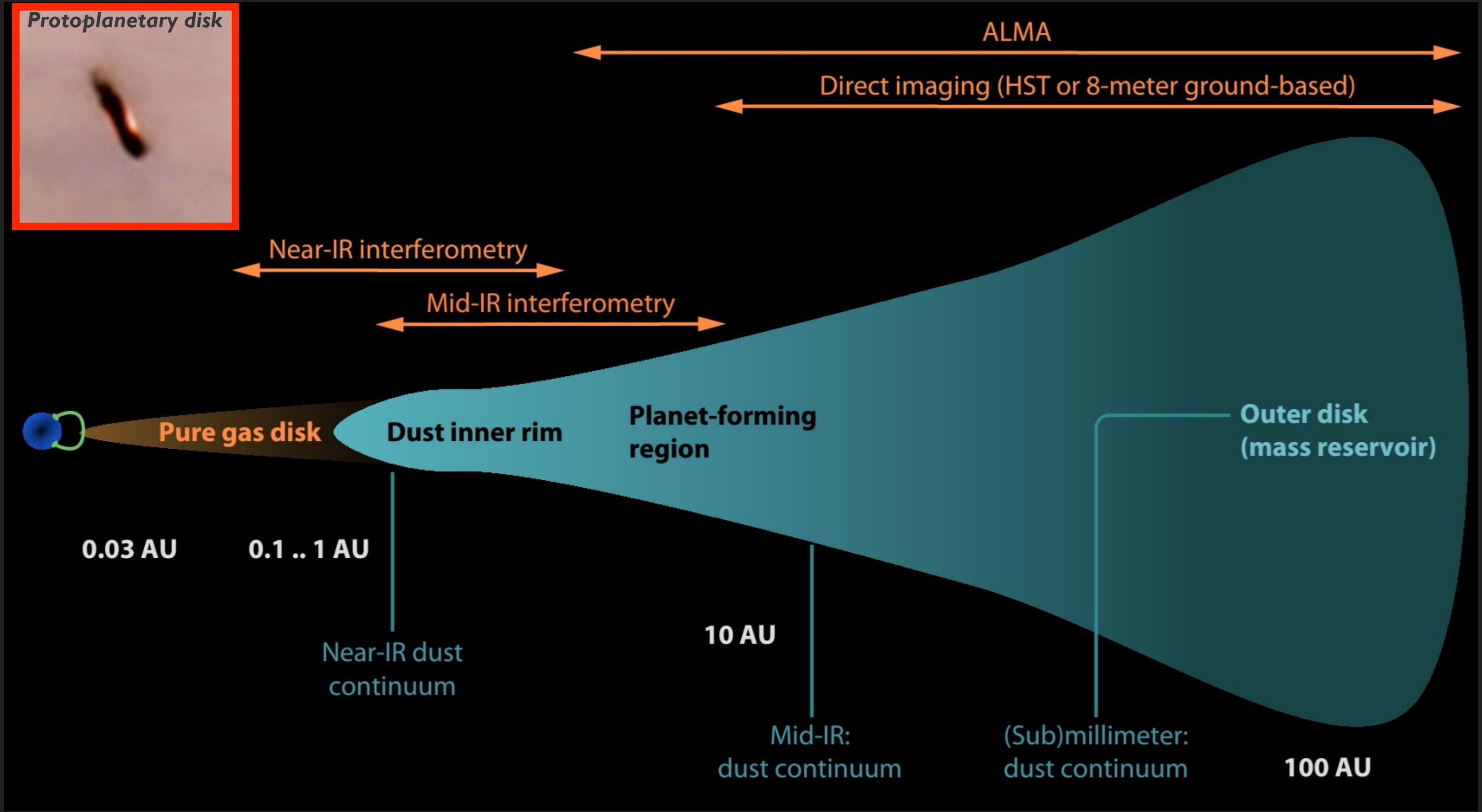
Leiden Observatory, NL

MATISSE Days, Nice | Nov. 2024

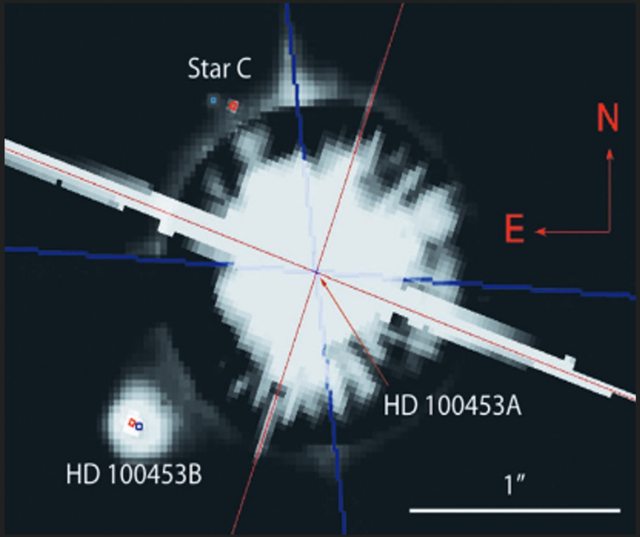
Schematic protoplanetary disk



Herbig Ae HD 100453

Transition disk with binary interaction

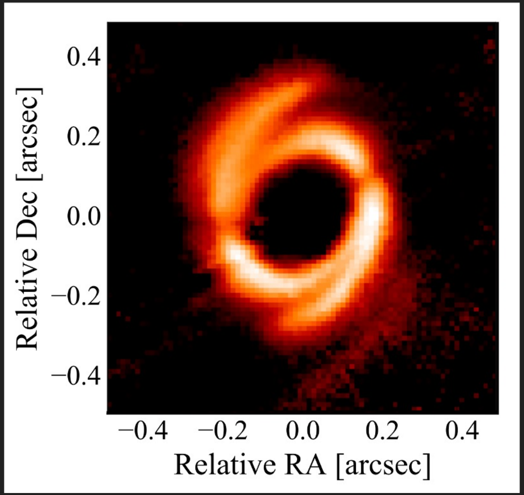
Parameter	Value
HD 100453	
Spectral Type	A9 – F0
Mass	$1.6 \pm 0.05\ M_\odot$
Teff	7250 ± 125 K
Age	6.5 – 19.2 Myr
Distance	103.61 ± 0.24 pc
Luminosity	$6.2 \pm 0.14\ L_\odot$
Companion	
Spectral Type	M4.0V – M4.5V
Mass	$0.18 \pm 0.03\ M_\odot$
Age	8 – 12 Myr
Projected separation	1.05", ~109 AU



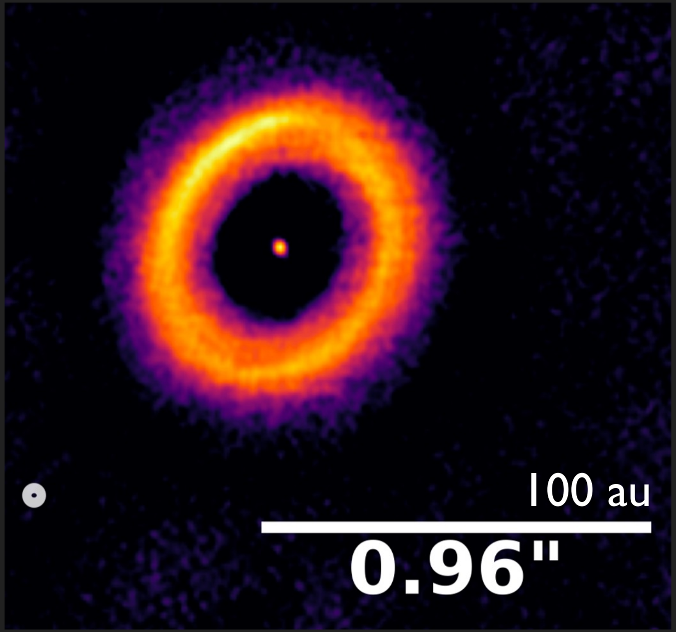
HD 100453: Protoplanetary disk with binary interaction

Benisty et al. 2017
Stapper et al. 2022

Infrared:
scattered surface light



mm:
thermal emission from large grains



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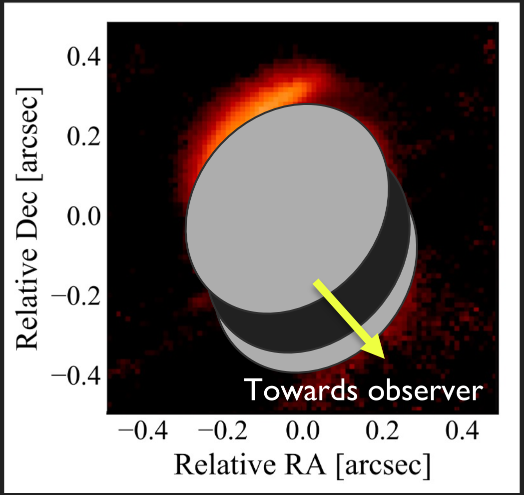

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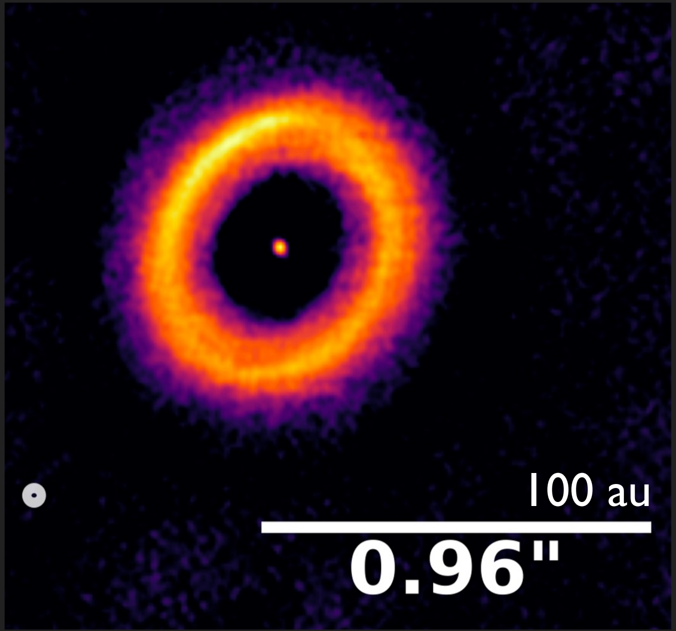

HD 100453: Misaligned inner disk causing shadow lane

Benisty et al. 2017
Stapper et al. 2022

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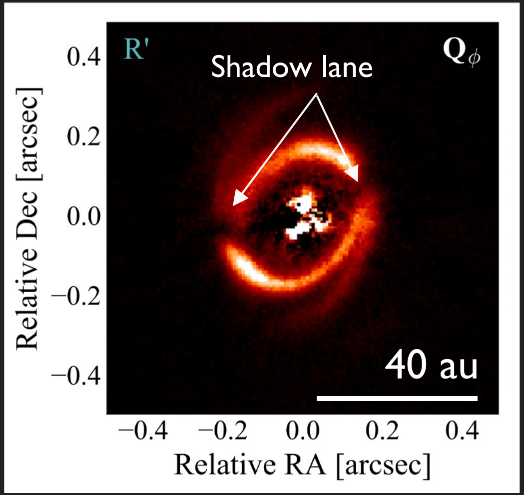
scattered surface light



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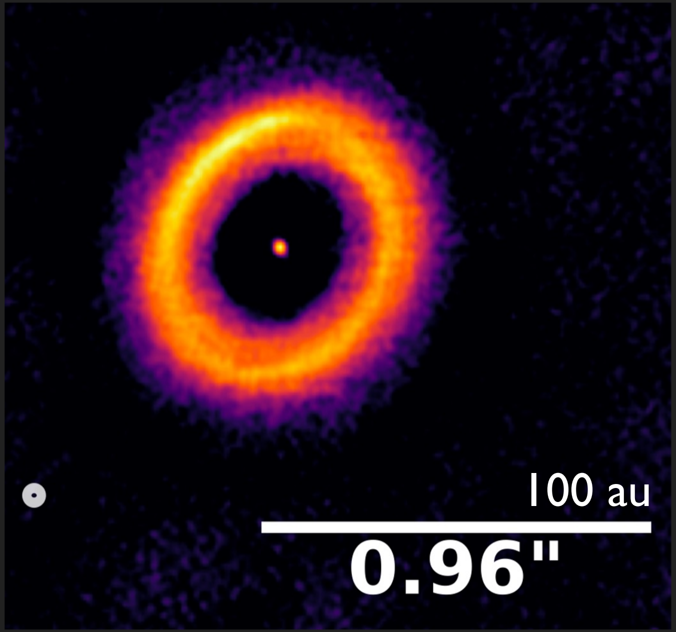

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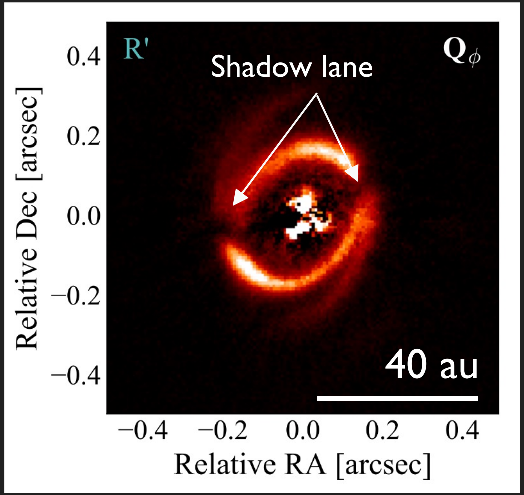

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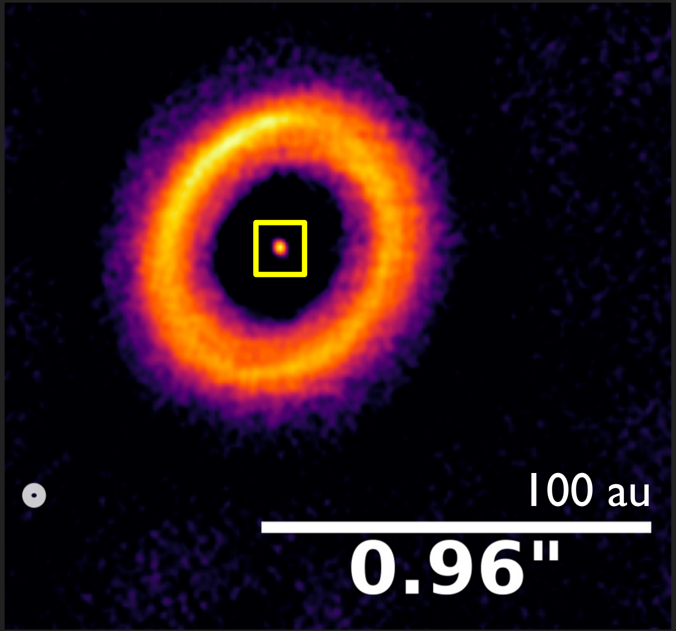
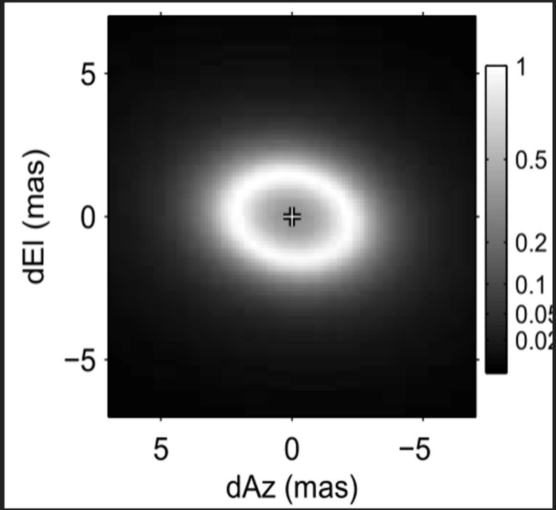


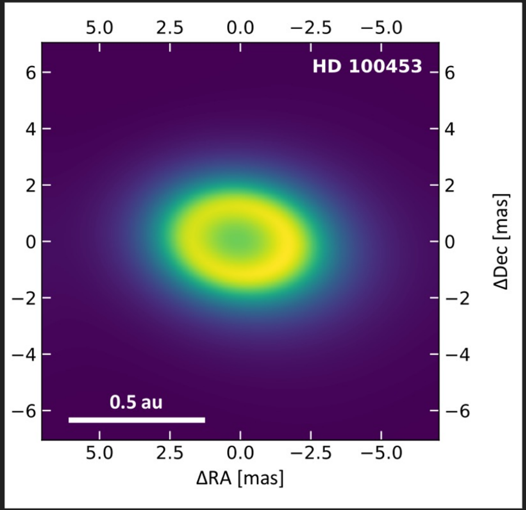
Strong inner disk misalignment

Lazareff et al. 2017
Bohn+ et al. 2022

PIONIER:
Thermal hot dust (1.5 – 1.8 micron)



GRAVITY:
Thermal hot dust (2 – 2.5 micron)



- Inc $\approx 46° - 48°$
  PA $\approx 80° - 83°$

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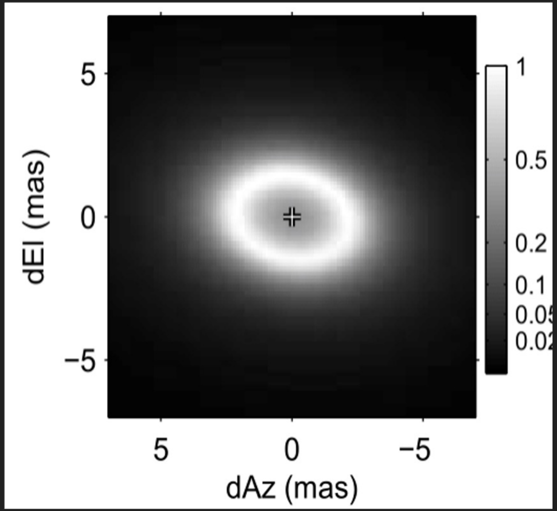

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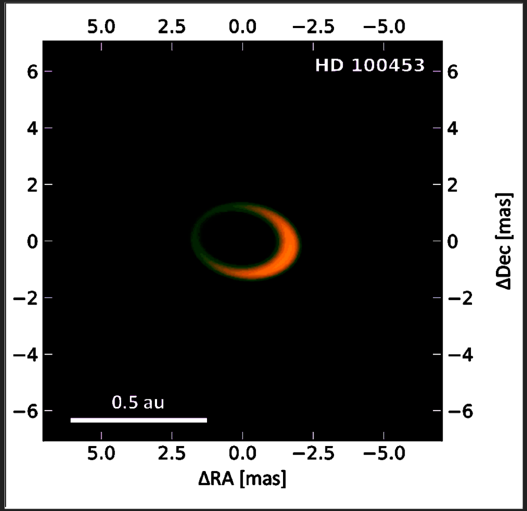
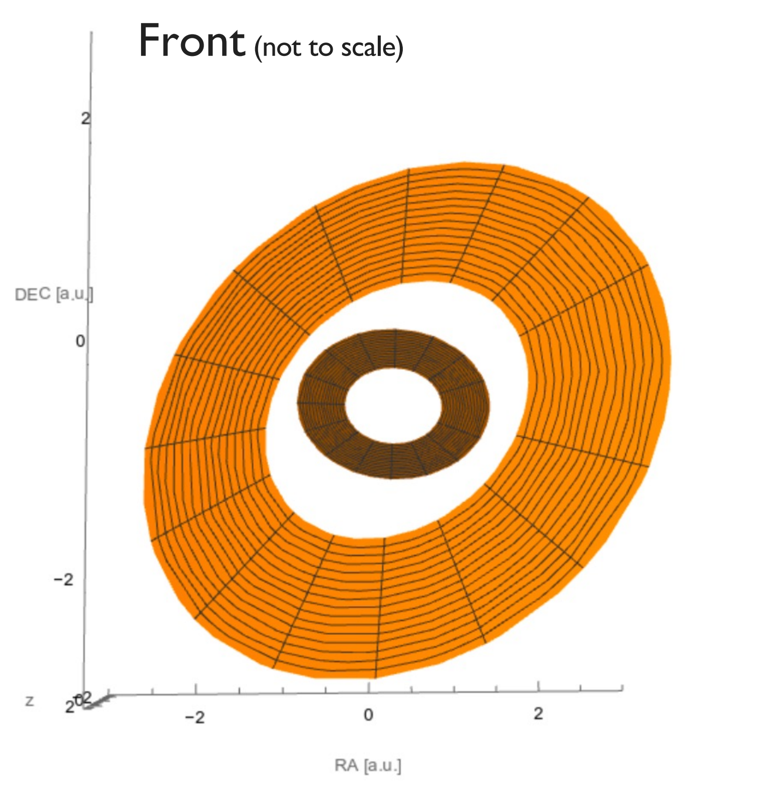
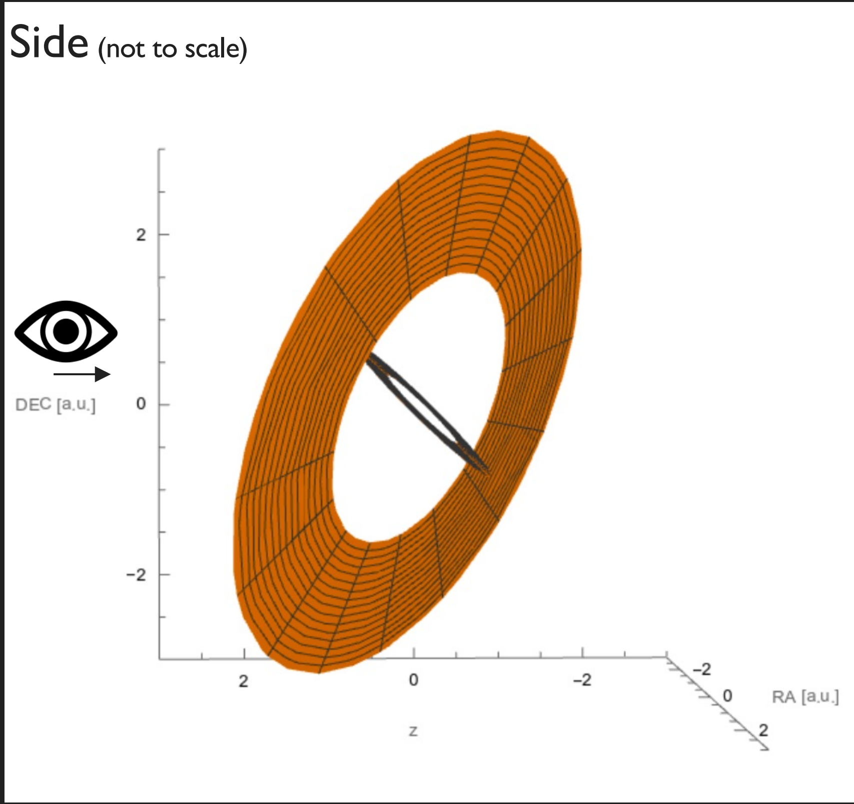


- Skw $\approx 14\%$
- SkwPA $\approx 254° \pm 4°$

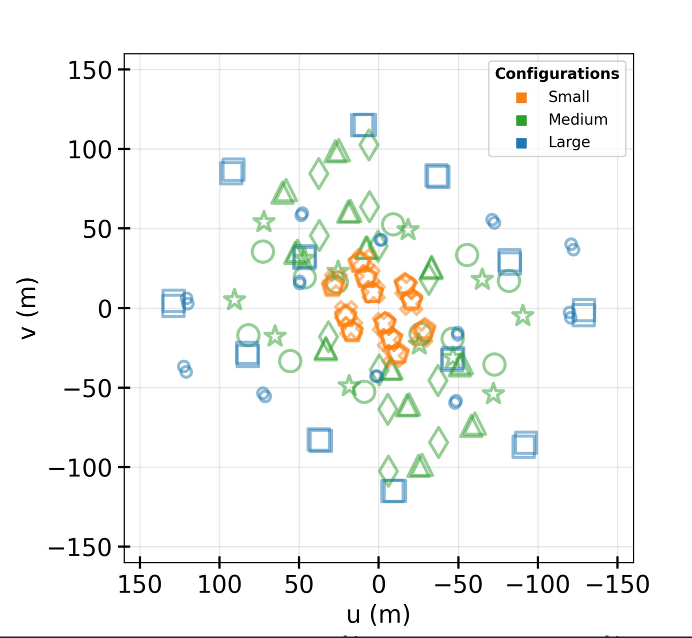
- Inc $\approx 46° - 48°$
  PA $\approx 80° - 83°$

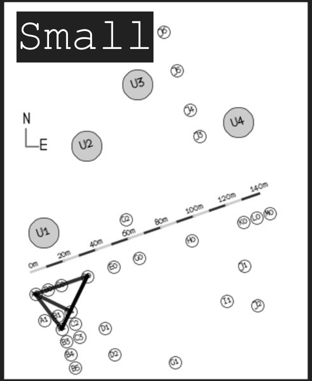
Schematic view HD 100453

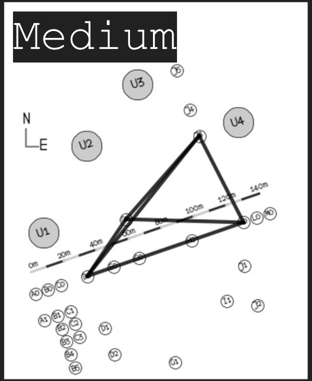


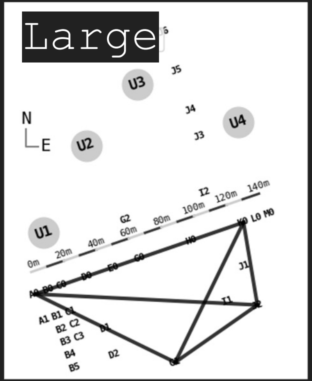


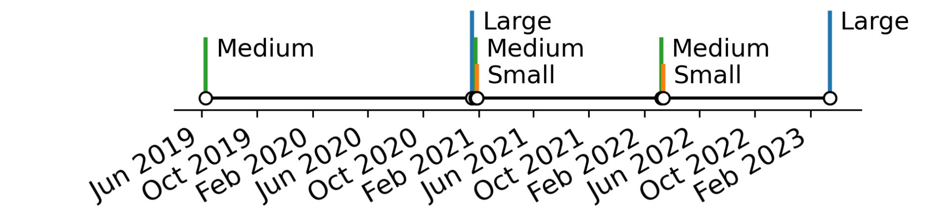
MATISSE observations (2019-2023) = 13 AT datasets





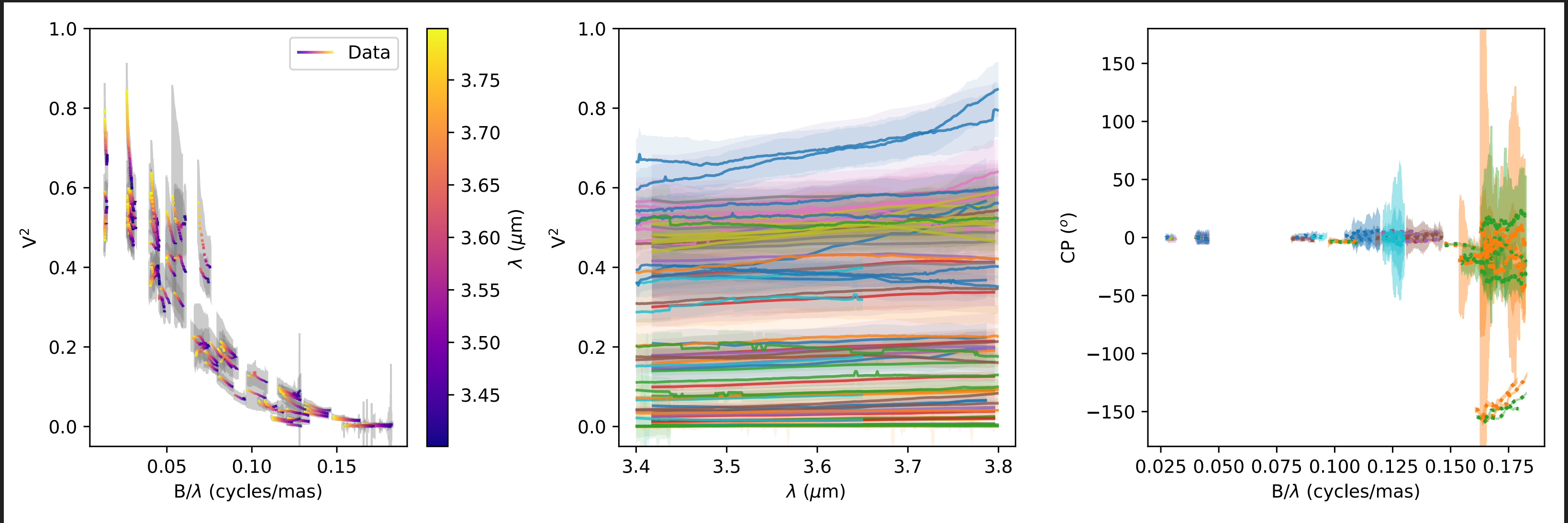






HD 100453 observations (2019 - 2023) - MATISSE

- 3.4 – 3.8 micron
- Big closure phase signal in multiple datasets!



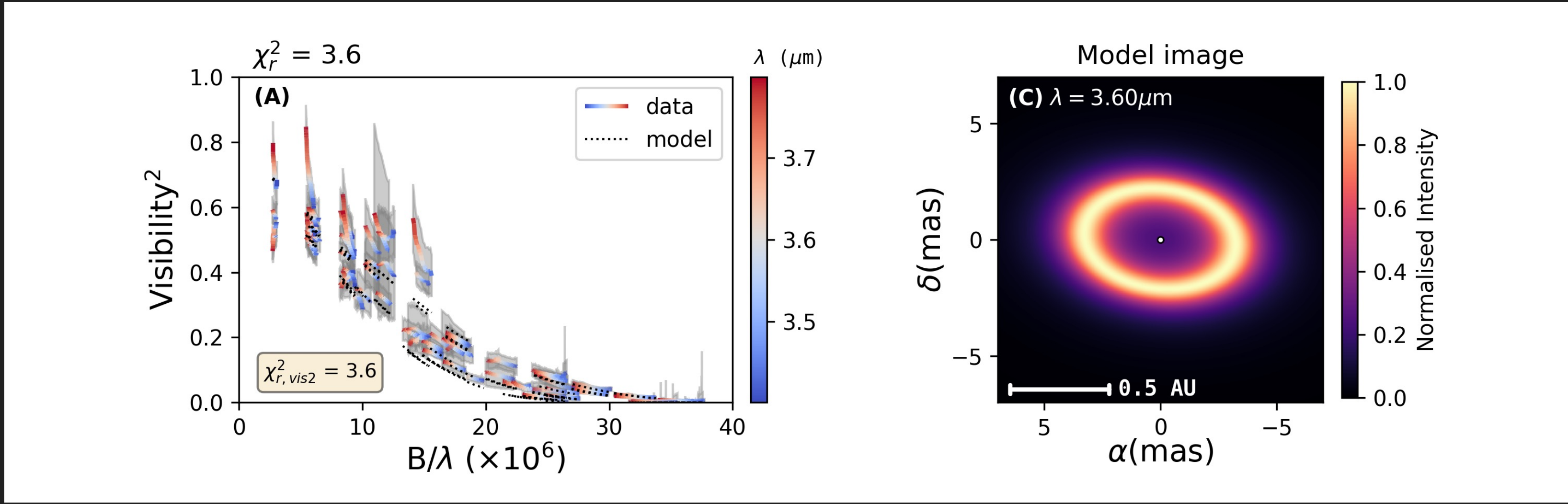
Parametric modelling

- Oimodeler frame work (A. Meilland+ 2024)
  https://oimodeler.readthedocs.io/

- Similar methodology Lazareff+2017 and Bohn+2022.
  Best model → Pseudo-Lorentzian kernel smoothed ring
  First order azimuthal modulation

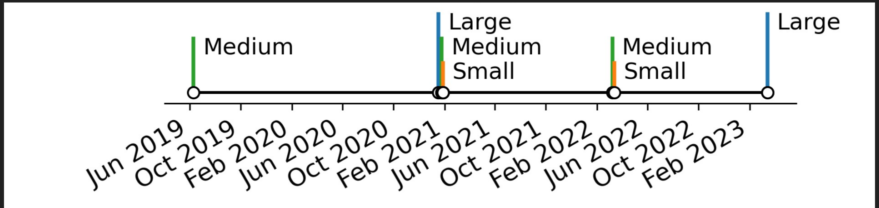
  + Stellar & Background terms

Visibilities show good agreement with previous work



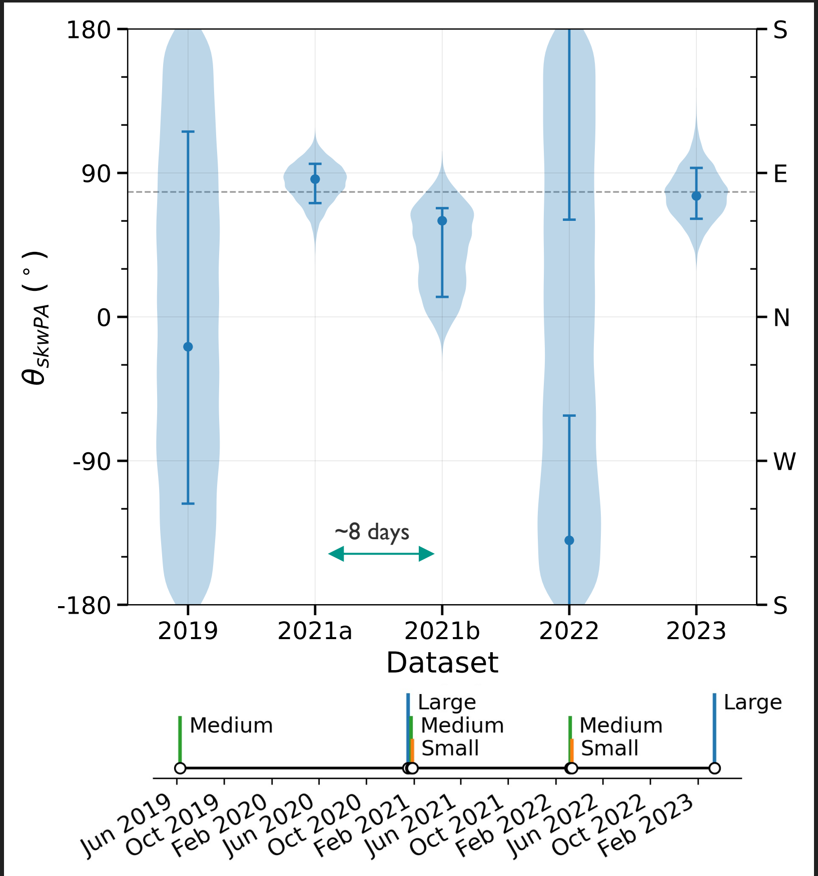
- Inc ≈ 49° ±10°
  PA ≈ 83° ±20

Multi-epoch fitting: does the asymmetry move?



Splitting medium/large datasets

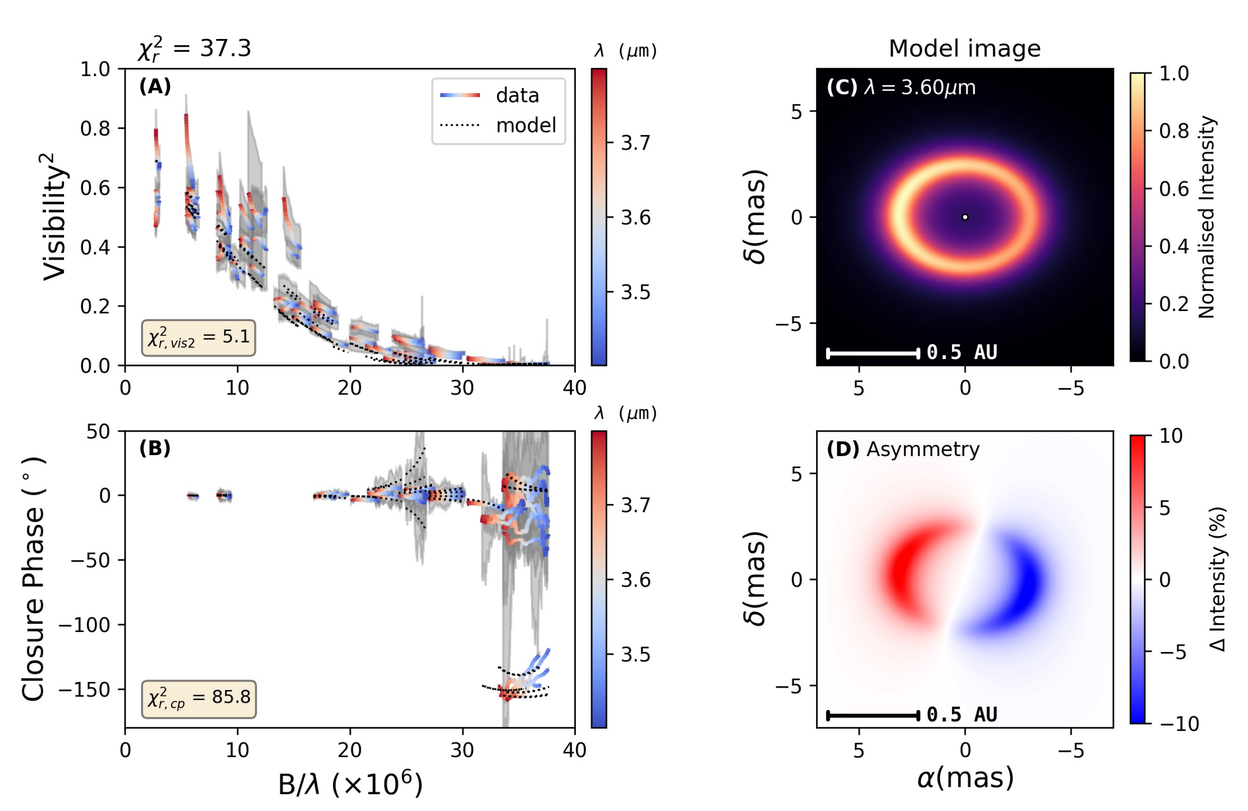
Asymmetry seems stationary over our observations.

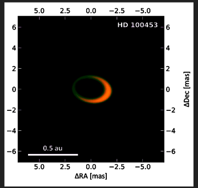


If Keplerian motion (~38d period)
[2021b] $\approx [2021a] \pm 80\,°$

Data points towards asymmetry being stationary
(although we cannot strongly exclude sub-Keplerian rotating structure).

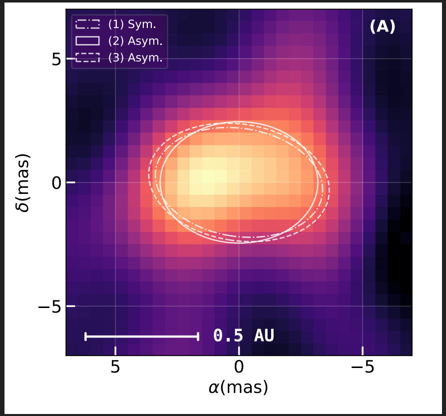
Find an asymmetry in ~stationary in eastern direction (!)



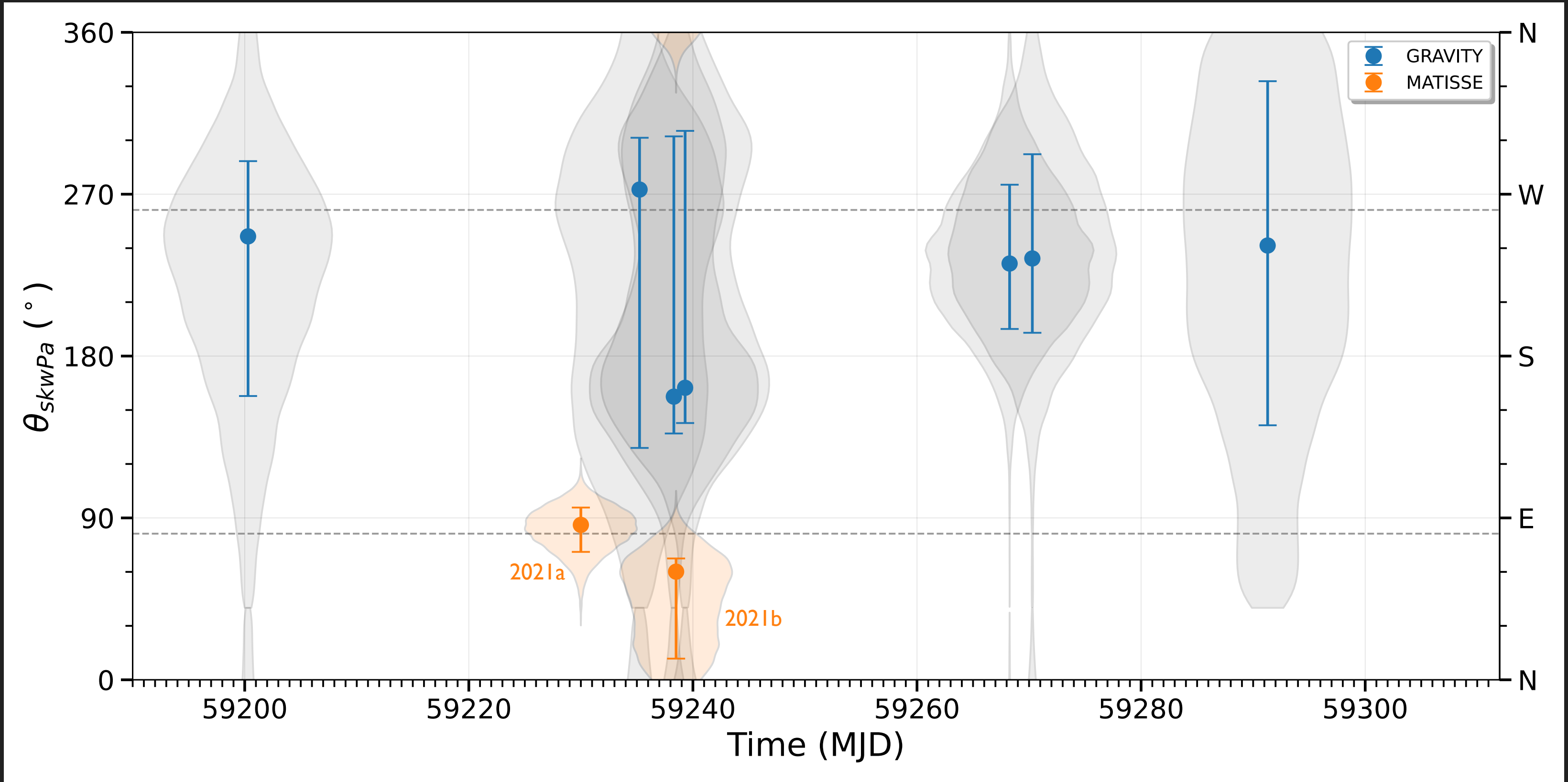


Bohn+ et al. 2022

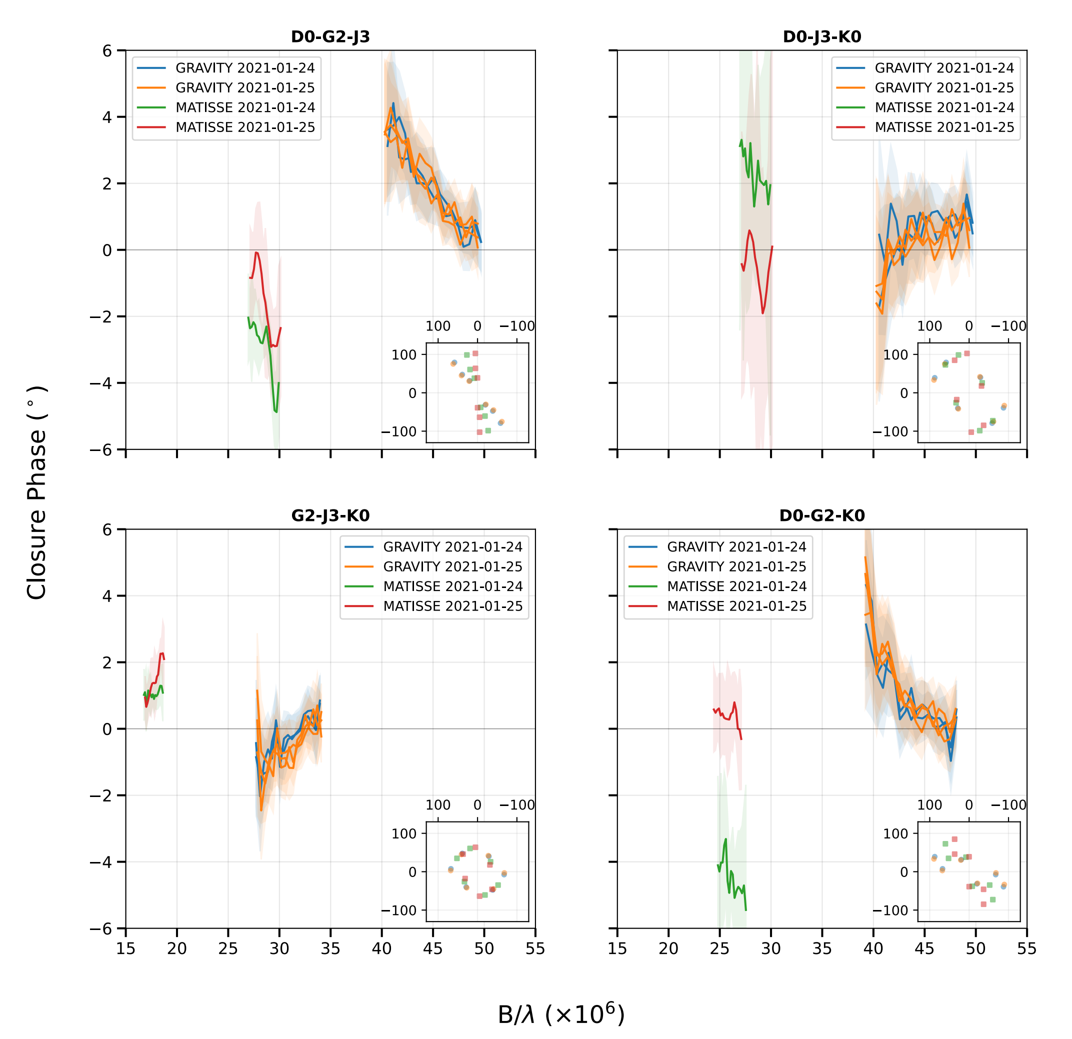
Reconstruction (Sparco)



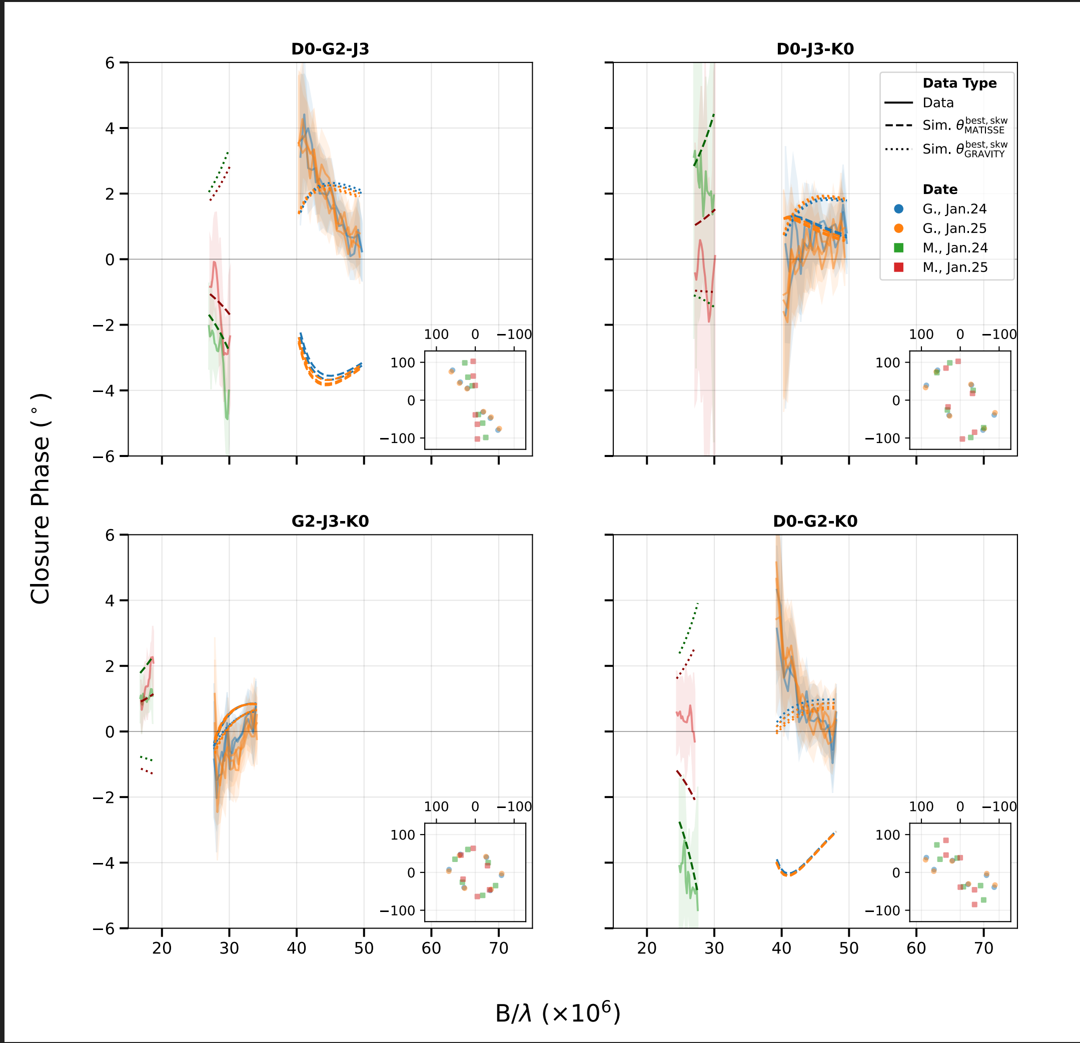
Similarly stationary in GRAVITY observations



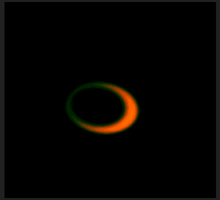
Chromaticity in closure phases MATISSE & GRAVITY



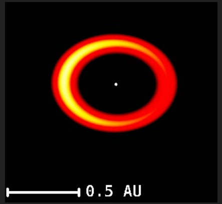
Chromaticity in closure phases MATISSE & GRAVITY



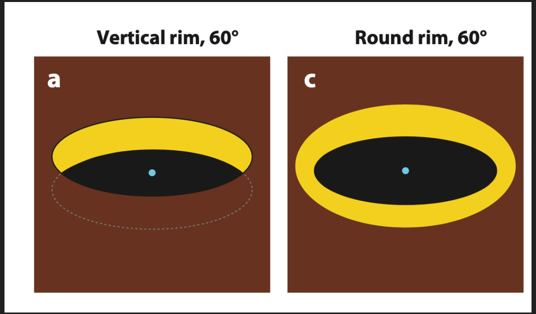
Dotted …



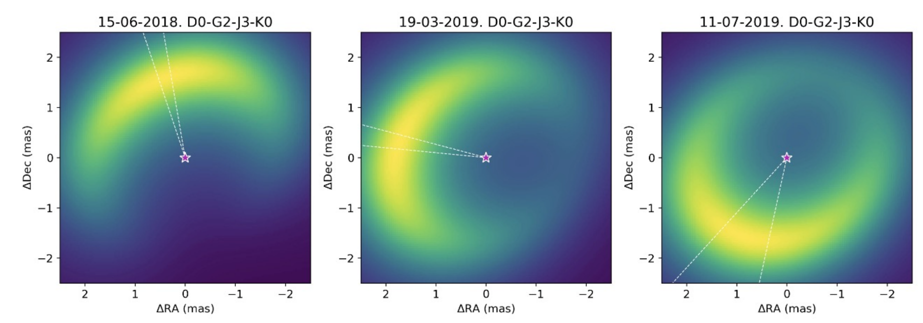
Dashed ---



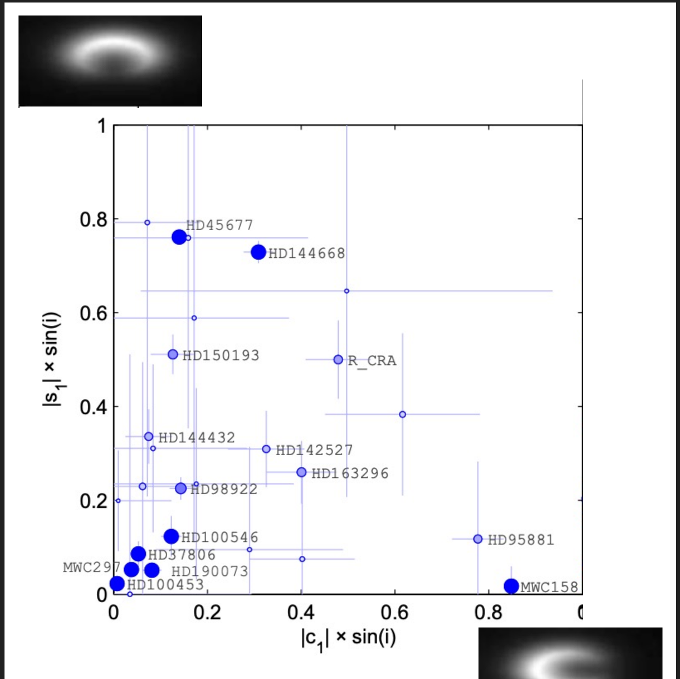
Refresher: Common asymmetry



Dullemond & Monnier 2010

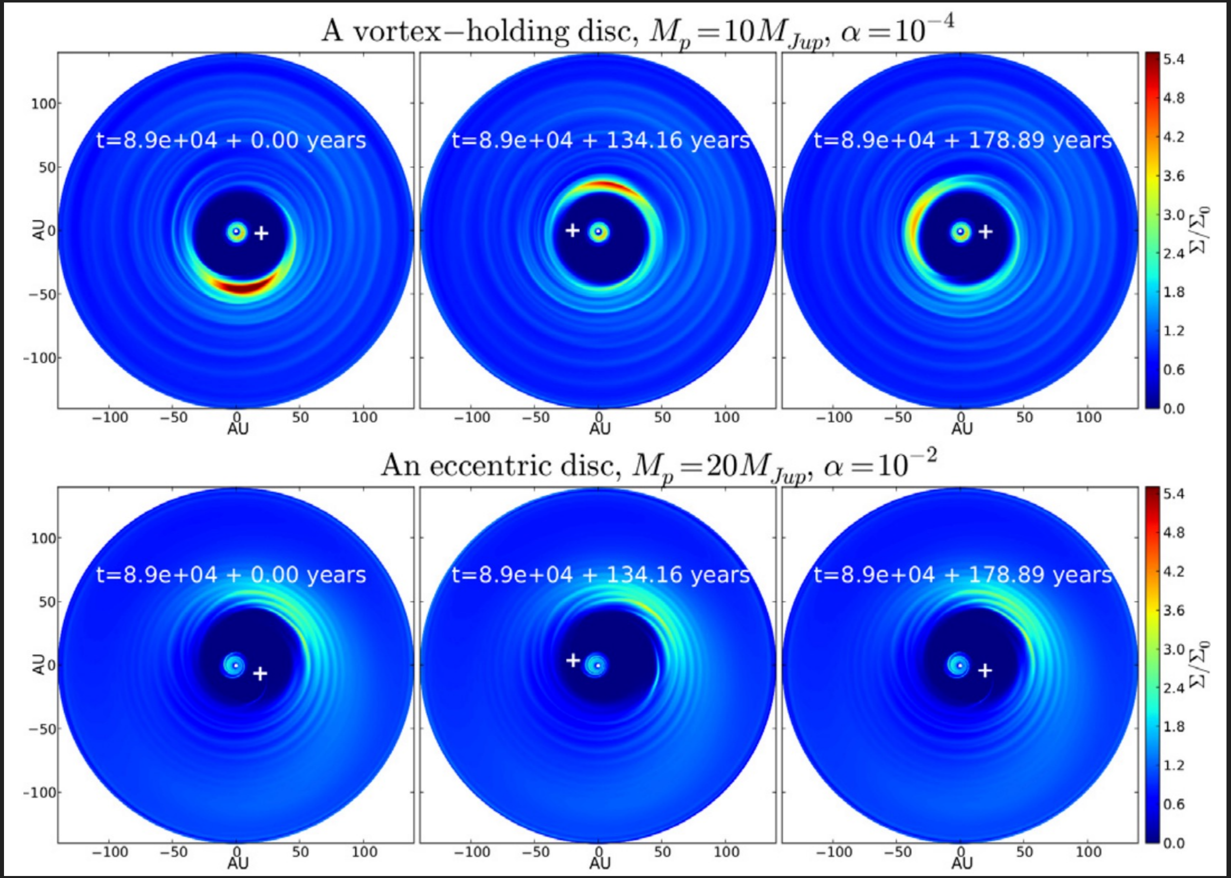


Gravity Col. 2024



Lazareff+ 2017

Planetary companion driven eccentricity?



Ataiee et al. 2013

Conclusions

- MATISSE L-band visibilities agrees well with previous work with H- and K-band w.r.t disk misalignment.
- After a thorough investigation of the data and reduction methods, we conclude that the observed chromatic 'mismatch' in closure phases between MATISSE and GRAVITY for HD 100453 seems a physical effect, not a result of errors in reduction or calibration.
- We detect an asymmetric dust feature in the L-band along the projected semi-major axis in the North-East direction, which contradicts the GRAVITY reported value by ~160 degrees. Temporal analysis of the data is inconclusive, but suggests that the asymmetry remains stationary over our few year observational timeline, hinting towards an eccentric inner disk.
- The discrepancy in the recovered skwPA is likely due to simplistic model assumptions, indicating a more complex chromatic asymmetric structure in the inner disk.
- An imaging campaign using simultaneous GRAVITY + MATISSE AT Medium/Large would be highly beneficial.